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SCIENCE

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THE NATURE AND PURPOSE OF EDUCATION[1]

Students of Michigan: From farm, village and city, from every state in the union, from every continent in the world, you have come to spend here from four to six years in the formative period of your lives. Why are you here? What has impelled you to leave your homes and come to this small city? While Ann Arbor is a pleasant place in which to reside, there are many other cities, both larger and smaller, more attractively located. We have no inspiring view of ocean, no picturesque lake, no majestic river, no towering mountain peaks, no vine-clad hills, no broad valleys, no historic associations, no ruined castles. Ann Arbor is a commonplace town, pleasant enough in its way, but without the material attractions of which a hundred other places may boast. What is the loadstone that has drawn you from near and from afar? It is the university. What is the university, why does it exist and what is your purpose in coming to it? Some universities have been founded to perpetuate theological creeds, some to serve as monuments to men of wealth and power, but neither of these motives actuated the founders of this university. It had its inception in the wisdom of the early settlers of this state, it has been and is maintained by the labors of their descendants. The rich and the poor contribute to its support. Many of the former send their sons and daughters to more aristocratic institutions and many of the latter are not able to send their children to any university, but all pay in proportion to their means to the support of this institution. What justifies the people of this state in imposing upon themselves the burden of taxation necessary to sustain this university? The total fees paid by

[1] A popular lecture to the students of Michigan University on Convocation Day, October 16, 1914.

you each year would not carry the current expenses for three months. The people of the state are, therefore, giving each of you more than four times what it received from you. Each of you becomes a debtor to the state. What does the state demand from you in return for its generosity? There is an implied moral contract between each of you and the state, and unless you intend to comply with your obligation to the state you should not be here. The university does not exist in order to support the saloons and billiard halls of this town nor to afford a comfortable residence for loafers, and the university authorities are not worthy of the trust imposed upon them if students of this class are permitted to remain here. This is not a reformatory institution, nor is it an asylum for the feeble-minded, the state having made provision elsewhere for those wanting in morality and intellectuality. Admission is a privilege and continued residence should be permitted only to those who show intelligence, industry and integrity in all proper functions of student life. Even admonition to more earnest work or better behavior is not a duty of the university teacher to his students. The purpose of the university is to better fit you for citizenship. With this end in view, the people of Michigan expend on you more than one million dollars annually, a sum which if capitalized at four per cent. represents twenty-five millions. This means that the amount annually paid for the support of this university is equivalent to a contribution of more than one third of a dollar from every inhabitant of the state. Is this expenditure justified? Why should the state be so generous and what obligation do you assume in accepting this generosity? If there be among you those who do not feel any responsibility in this matter, in all honor let such depart immediately. The state does not educate you in order that you may make a living more easily. It does not intend to make shyster lawyers, who fleece their clients, nor quack doctors who rob the sick and afflicted, nor ignorant engineers who build unsafe bridges, nor indifferent school-teachers who perform their tasks perfunctorily, nor lazy farmers who impoverish the soil; but it does hope to educate jurists who will see that only wise laws are enacted and in their administration justice shall be done, physicians who will render the sick the best service and protect the well from disease, engineers who will develop the natural resources, school teachers who will train the young in body and mind, and farmers who will improve the fertility of the soil. The state realizes that intelligence, industry and integrity are the great factors in the betterment of the conditions of life and it seeks the development of these attributes in all its citizens. In a generous spirit it offers its training in these qualities to all who are capable of development along these lines whatever their nationality, color or creed may be. One who is lacking in any one of these cardinal virtues can not be of service to the state and should not seek his education in a state university. Without intelligence development is impossible; without industry life is barren; without integrity the individual is a menace to the state.

In a broad sense, education has been defined as the modification and development of behavior through experience. Since behavior is determined through the mechanism of the nervous system, education is concerned especially with the function of the nerves. Man comes into the world the most helpless of all animals. At birth the child is incapable of locomotion and of finding unaided its food supply. For months, and indeed for years, the child remains in this helpless state. The dog in the first six months of its life learns more than the child does in years. It is the superiority of his nervous mechanism that has given man dominion over the earth and all that is therein. We need sound bones, strong muscles and healthy organs, because these render the development of the nervous system possible, and the health of the body, as a whole, is essential to the well-developed man. We can have no correct conception of education without some knowledge of the mechanism employed in its acquisition. Briefly considered, the nervous system consists of receptors or special senses, which are stimulated by the

environment, of conductors which transmit the stimulation to the central organs and of effectors which control and direct the responses to the stimuli. The primary function of the nervous mechanism is to provide paths of conduction between the receptors and effectors. The first breath of air at birth starts the machinery of respiration. Irritability and automatism are properties of all living things. Even unicellular organisms, amebæ, for instance, in which there is no nervous tissue, automatically respond to external stimuli, such as food, and changes in behavior or rudimentary and limited education can be developed in them. As cell differentiation is evolved the structure of the nervous system becomes more complicated and its functions are more diversified and effective.

A sense receptor, such as the eye or ear, the sensory nerve, such as the optic or the auditory, the nervous center to which the impression is conveyed and the motor nerve, through which the response is transmitted, constitute the "reflex arc." Reflex action is the simplest function of the nervous system. Strong light induces contraction of the pupil, the sight or odor of food causes the saliva to flow, pinching the flesh is followed by muscular movement. These are examples of innate reflexes. The normal child comes into the world possessed of these reflexes. A large part of education consists in the coordination and development of these innate reflexes. Walking, talking, reading, writing, are examples of coordinated, trained reflexes.

The first lesson we learn in investigating the mechanism of education is that the sense receptors must be in good condition to start with and must be kept in the highest state of efficiency as we proceed. The receptors through which our behavior is modified and developed by environment are the five senses, seeing, hearing, touch, smell and taste, each of which, on close analysis, is found to be complex. All primary knowledge reaches the brain through these sources. In no other way can environment modify our behavior or can we be educated. The dictum of Locke, "Nihil in intellectu est quod non prius in sensu," is not refuted by the addendum of Leibnitz, "Nisi intellectus ipse." When the senses are defective in function, illusions, hallucinations and delusions control us and dominate our conduct. The senses may be primarily defective and to some extent these defects may be removed by medical skill. When normal in mechanism these functions may be impaired by poisons introduced from without the body, such as alcohol, or by those generated within the body, such as those due to fatigue or to disease. Although the truth expressed in the Latin proverb, "Mens sana in sano corpore," has come down to us from classical times, educators have been slow to realize its force. Indeed, when mystical scholasticism formulated educational ideals affliction of the body was believed to be essential to the highest development of the mind. Fortunately, even educators, one by one, with some reluctance, are awakening from their dreams and becoming interested in scientific investigation. Greater benefits in educational methods have been obtained by observation of the effects of altered environment on the behavior of animals than have been evolved from the inner consciousness of the greatest genius. Appreciating the fundamental importance of normality in securing an education, this university is developing a splendid system for the supervision of the health of its students. However, the health of each individual is largely in his own keeping, and I wish to say that idleness, alcoholism and sexual vice remain the most potent factors in student wreckage. With senses untrained from idleness and benumbed by dissipation, the individual is a failure in college and in the greater school of the world.

Certain complex reflexes are known as instincts. These play an important part in education. All instincts are not manifest at the time of birth, but develop with age and are influenced by the evolution of the individual, as a whole. The instinct of play manifests itself in every normal child and the same is true of the instincts of acquisitiveness, construction, possession, self-assertion, anger, self-abasement, rivalry, pugnacity, etc. These

need to be controlled and directed, and this constitutes an important part of education. They are inherited, but are subject to marked modification by environment. For instance, the instinct of imitation is one of great potency in shaping our conduct and in determining not only our own lives, but of those about us. In this lies sufficient justification of state education. One scientific farmer in a community enhances the value of all the farming land about him, because he demonstrates the productivity of the soil. One honest, learned lawyer reduces litigation and a skilful physician not only alleviates the suffering of the sick, but prevents the spread of disease. The highest purpose of this university is to train leaders of men, those whose influence among their fellows may always be in the right direction.

Success will depend largely upon the environment under which you live while here. This can not be wholly determined by the university authorities. To a large extent you will educate one another.

A part of education consists in inhibiting reflexes and suppressing misdirected instincts. The only way in which this can be done is by the cultivation and exercise of certain other reflexes. As we shall see later, nervous impulses travel most easily over well-worn pathways. A function frequently performed proceeds automatically and to the exclusion of antagonistic tendencies. One of the most difficult things the untrained student has to contend with is diffuse activity. He tries to study, but outside stimuli of vision, hearing, etc., bombard his sensorium and demand his attention. Training is essential before calls to purposeless activity can be ignored.

The first impression which one receives in studying the structure and function of the nervous system is that it is a grossly defective mechanism. The elements of which it is composed consist of nerve cells with axons and dendrites. The dendrites are supposed to receive the stimuli and the axons to conduct them to the next unit. Between these units, called neurones, there is no direct structural connection. The axons of one unit come in more or less direct contact with the dendrites of the next, but each neuron is organically quite distinct from all others. The apparent imperfection lies in this absence of direct connection. The point of contact between two neurons is known as a synapse and at this point there is more or less resistance to the transmission of the stimulus. This apparent imperfection is, however, in some respects at least, a benefit. Were it not for this delay the brain would be stormed continuously by stimuli from the outer world and orderly thought would be quite impossible. Without these apparent imperfections, sleep would be less restful and anesthetics would not be able to relieve pain. Education consists partly in improving these connections. A pathway through the nervous tissue having been once opened is more easily followed by subsequent similar stimuli. This renders possible the formation of habits. The more frequently a given pathway is traversed, the more easily stimuli pass, until finally transmission occurs without conscious effort. The first attempt to learn is more or less laborious, but with each repetition the resistance becomes less and finally the thing is done automatically. Effectiveness is largely the result of the formation of good habits. In this way the expert is developed. The best preparation for doing anything is the fact that you have once or oftener done it, and the more frequently it has been done the more certainty is there in repeating it. The beginner in telegraphy must give attention to each letter, then he thinks only of words, and later he advances to phrases and even to sentences.

In learning of this kind, progress is not always uniform. After reaching a certain degree of proficiency there is a period in which there is no apparent progress. These periods are known as plateaus. All students are familiar with these depressing states in which effort seems without avail, but with persistence the curve of learning suddenly begins to rise and the elation of success is the reward.

The question of the transference of skill acquired in one branch of learning to another has been debated among psychologists, but the

weight of evidence is that it is not possible. Being an expert mathematician does not make one an authority in law or medicine. The neural pathways opened up in the pursuit of different branches of learning are not the same. They may lie quite far apart and expertness in one line does not imply even soundness of judgment in another. This is an important matter in education and will receive further attention later.

The formation of habit is common to all animals, and habits have a marked influence on behavior. We do things so often that it becomes difficult to refrain from doing them when the conditions under which they have been done recur. The most forceful teacher of my college days was wont to say: "Man is but a bundle of habits and happy is the man whose habits are his friends." At twenty, it seemed to me that the force of this saying lay in its sonorous quality. At sixty I realize that its strength lies in its truth. The young scout the idea that they can not indulge in a vice occasionally without becoming a victim. The chains forged in the smithy of habit are strong in every link. They may safely hold us in the heaviest storm or they may drag us to the bottom of smooth seas. Another mistake often made by youth is the belief that every experience is helpful. There is no other commodity for which we pay so dearly and the price often is health, happiness and even life.

Some stimuli make such deep and lasting impressions on the central nervous system that the picture may be recalled without the recurrence of the original stimulus. This is memory. Jennings has shown that there is some evidence of memory even in unicellular organisms. This becomes more marked as the animal structures, especially the nervous system, develop. Even a spider learns by experience and alters its behavior to its own benefit, when repeatedly subjected to like conditions.

Colvin says:

> Memory is a fundamental phenomenon of organic life. In its widest sense it signifies the fact that impressions once received by an organism are retained for a greater or less period and that this retention is indicated in the modified behavior of the organism. The evidence of memory in animals is their ability to profit by experience. A white rat is placed at the entrance of a maze at the center of which is food. The animal moves about in an aimless manner until at length it reaches the center. If on succeeding trials the rat shows an improvement in the accuracy and rapidity with which it moves about the maze, this means that its earlier attempts have in some sense left their effects; they have modified subsequent conduct. Memory, when used in this widest sense of the term, lies at the basis of all learning. It is a measure of educability.

There are three important factors in memory. The impression must be "stamped in." It must be correctly associated with other impressions. It must be subject to recall and proper recognition. The strength of the impression is dependent upon many factors. The brain may be so altered by inherited defect, trauma, senility, fatigue, disease or toxic agents, that effective and lasting impressions can not be made. So long as the brain remains in the abnormal condition its receptivity can not be improved. The mentally defective can be educated to a certain point, but can go no farther. An impression may be "stamped in" by the force or unusual character of the external stimulus. The external world demands the attention of the individual and an unusual sight, noise or other sensation makes a never-to-be-forgotten impression. This is known as passive attention and is common to all animals. It is the basic principle in all attempts to modify behavior through hope of reward or fear of punishment and is highly effective in the control and training of the lower animals and ignorant men, but loses in power with the development of intellect. However, in this and other universities this appeal to increased effort is employed in the form of grades, admission to special societies, the bestowal of insignia of distinction, etc., and on most men in our stage of development it is not without effect. The approval of our fellows as shown by social, political and intellectual preferment, still proves a potent incentive to increased effort. With the development of intellect, passive attention is largely supplanted by the active form. In

the latter the individual selects the stimuli which are to make permanent impressions. An important function in the accomplishment of this purpose is the rejection of stimuli believed to be unimportant or harmful, and seizing upon and fixing of those recognized as of greatest value. In this selection lies the pathway to wisdom. It determines the ideals of the individual. It shapes the ego and sets the lines of future development. The memory pictures photographed in the highly labile molecules of the brain constitute a record of all our available knowledge, not only that gained through personal experience, but that acquired from any source. We rehear the spoken and reread the written word. We recall the facts of history. We utilize without conscious effort in our daily dealings the mathematical skill acquired in childhood. We make practical application of the scientific discoveries of the past in supplying ourselves with the necessities and comforts of life. We enjoy the literature of all nations in all ages. In short, the storehouses of learning to which we have access are practically limitless in their wealth, and from this we may select at will and appropriate to our own use without diminishing to the smallest degree what is left for others.

In order to be of greatest service, memory pictures must be clear and properly placed. Clearness and association are essential to prompt recall and correct recognition. Memory, like all other functions of the nervous mechanism, is capable of improvement by exercise. When memory pictures have a faulty setting, they may influence behavior disastrously. The old man thinks all this talk about impure milk killing infants and infected water causing typhoid fever is nonsense, because all his life people, both young and old, have been drinking dirty milk and polluted water. He does not know or recognize the fact that many even within his own circle have died from these causes. In his experience these facts have not been recognized as possessing any causal relationship. Half his children have died from the summer diarrheas of infancy and others have died in youth from typhoid, but he has always connected these bereavements with the world-old belief that disease could not be prevented nor death delayed. The failure to properly correlate experiences or their memory pictures is one of the things which prevent many elderly people, especially the untrained, from adjusting themselves to advances in knowledge. Many superstitious rites and ceremonies have their origin in the faulty conception of cause and effect. Many reason post hoc ergo propter hoc. This faulty logic is still a strong support of charlatanism in its many survival forms.

The study of the structure and function of the nervous mechanism makes plain what should be attempted in securing an education. We have seen that in the acquisition of knowledge pathways to the cerebral cortex must be opened up. Conduction of nervous impulses meets with resistance as it passes from one neuron to the next. This resistance grows less with each traverse of the impulse along the same path, and with frequent repetition the trail becomes so smooth that impulses pass through without conscious effort. It is easier to open up pathways to the cortex in youth than in later years because the lability and plasticity of the nervous tissue decrease with advancing age. However, lines of conduction established in the plastic period are never obliterated save by disease or death. Even with approaching senility, when the opening of new lines is impossible, those established in youth continue to operate. Truly, learning becomes the solace of age. The educated octogenarian remains in sympathy and intelligent touch with the outer world, while his untrained brother finds himself isolated and marooned on a small barren island. Furthermore, it has been demonstrated that the lines of conduction which serve in one department of learning are useless in the conduction of information from other sources. The acquisition of mathematical skill does not give special preparation for historical erudition. These elemental psychological facts indicate that in youth training of the nervous system should be broad, the purpose being to estab-

lish many and diversified sources for the supply of mental pabulum. Symmetrical exercise is as essential to the normal development of the nervous system as it is in muscular training. Athletes are not made by putting all muscles save one in plaster casts and exercising the free one, neither can the functions of the brain be properly developed in such a way.

What are the fundamental subjects which should form the basis of education? It goes without saying that the educated man must know his own language thoroughly. He should possess a large vocabulary and should select his words and shape his phrases and sentences with reference to smoothness of diction and clearness of statement.

Language is the medium of exchange in mental commerce and it must be on a gold basis. Fortunately in this country dialects are not sufficiently developed to interfere with intelligent transfer of information. However, we are known for our diversified richness in slang. Some of these expressions are highly illustrative of multum in parvo in speech, sound in sense, rich in humor and forceful in meaning. The function of the educated man in regard to these colloquialisms consists in the suppression of the atrocious ones and the regulation of others. Next to color, speech is most powerful in fixing dead lines across the paths of individual advancement and usefulness. A man who is constantly blundering in the use of his native language can not be long tolerated among the educated, whatever his virtues may be. In European countries, dialect is a potent factor in class distinction. I never fully appreciated this until I met with the following experience in southern Italy. On a drive I saw a beautiful villa, picturesquely situated, quite new and untenanted. On my return to the hotel I asked an intelligent appearing man concerning the villa. He became quite excited and in broken, but plainly intelligible English he made the following statement: "I was born a peasant in this community. I never spoke Italian and knew only the local dialect. At sixteen I went to New York. During the forty years of my residence in that city my highest ambition was to accumulate enough wealth to enable me to return to Italy and to participate in its affairs, concerning which I kept myself thoroughly posted. Four years ago I closed my business in New York and returned to this place. My dreams were now to be realized. With much pride I purchased land and built the villa you have seen. But the moment I attempted to move in economical, social or political matters, I found a dead line I could not cross. I did not speak Italian. I do not blame those who repulsed me. You would not have at your table an American who did not speak correct English. In New York I spoke only broken and incorrect English, but all said Mr. Blanco is Italian and we do not expect him to speak correct English. The villa can rot. I am going back to New York." Even in this country and in university circles I have known men who show lack of fundamental education by lapses in speech. Some years ago I was called one morning into the country where a German farmer asked me to lance a "bile" on his arm. On my return to town I saw a university instructor who told me that he had been vomiting "boil" all morning. A temporary colleague of mine, a man of much merit, frequently said: "I done it." Another said: "them there things." It is needless to add that these men found themselves out of place in a university faculty. There is one peculiarity about men of this kind; they are infuriated at the most delicate attempt of a friend to help them in their defects. Every educated man should speak and write correctly by habit.

The study of Greek and Latin is a great factor in the comprehension of other languages partly derived from these. Moreover, one who is limited in his reading to translations, whether the original be in ancient or modern speech, loses much of the force, beauty and spirit of the author. It is true that there are translations which equal and a few which improve the originals. As one who has made scientific work his special endeavor during the entire period of his adult life, the speaker believes that the student who has

never dug Greek roots nor pruned Latin stems has missed much in both pleasure and discipline. If a bit of personal experience be permitted, the speaker testifies that the first author to quicken the pyramidal cells of his cortex was Virgil, and to-day when recreation is sought the only book preferred to Virgil is Dryden's translation of the same.

While an educated man's linguistic ability may be limited to English, inability to read French and German handicaps him, delays acquaintance with important discoveries in various realms of knowledge, and limits his mental vision. To scientific workers a reading knowledge of French and German is quite essential. There are splendid nuggets of science and glittering gems of imagination encased in Italian, and sparkling jewels of humor encrusted in Spanish, but these, with many other languages, both ancient and modern, can hardly be placed in the list of educational essentials, however important they may be to the special student or for direct vocal intercourse. When philologists grow away from the false idea that centuries are necessary for the development of effective language and when nations recognize that there is no need of limiting verbal and written intercourse by political boundaries, man will use a world language, more perfect in structure, more forceful in expression and elegant in diction, than any now used. This time, like that of universal peace and good will, now seems a long way in the future.

Man needs figures as well as words. His sense perceptions are registered in numbers. They take various shapes. He perceives not only plain surfaces, but extension in geometrical forms. He needs figures in all his mental concepts. Some of the lower animals can count in small figures, while those of man are unlimited. He must establish units of measurement, linear, square and cubical. The external objects which stimulate his sense organs and photograph themselves on the sensitive plates of his brain vary in number, shape and size. Every educated man should know mathematics through plane trigonometry.

History is a record of the experiences of past generations and of these no man can afford to be ignorant. The child comes into the world without inherited knowledge and the individual can not depend upon his own narrow and limited experiences. The brute has this to direct and modify its behavior, and we have enough of the brute disposition left in us to make us slow to profit by the experiences of others. This is a marked defect in youth. The young man believes that he can take personal, economic and social risks in which thousands of others have fallen, without injury. He believes that he was born under a propitious star, trusts his luck and goes to ruin by the same path that others have traveled and that more will continue to travel. If this were true only of individuals, it would not be so bad, but it is equally true of nations or rather of those who control nations. Some man, laboring under the delusion that he is a chosen son of destiny, brings about some horrible catastrophe which results in death, sorrow and suffering to the present generation and places chains of bondage on the unborn.

I have defined education as the modification of behavior by experience, and a large part of this experience which is to determine our behavior should be learned from history. History in the wide sense in which I am now using the word includes the record of all human experience. It is national, communal and individual.

Fuller says:

> History maketh a young man to be old without either wrinkles or gray hair; privileging him with the experience of age, without either the infirmities or inconveniences thereof. Yea, it not only maketh things past present, but enableth one to make a rational conjecture of things to come. For this world affordeth no new accidents, but in the same sense when we call it a new moon, which is the old one in another shape; and yet no other than it hath been formerly. Old actions return again furbished over with some new and different circumstances.

Failure to profit by the experiences of the past leads to the most serious disasters that befall our race. Study history. Study it in college and out of college. Devote much of your energy to it in youth, find time for it in

your busiest years, and do not neglect it in age. For if it maketh the young old without infirmity, it keepeth before the old the pictures of the eternal youth of the race.

There has been some discussion among partisan educators about the relative merits of humanistic and scientific studies. The symmetrical and effective development of the nervous system demands both forms of exercise. The man who knows the classics and nothing more is blind and deaf to much which is of the highest interest to both himself and his fellows. The man whose knowledge is confined to some narrow domain of science is equally out of touch with much that is necessary to make life rich in either endeavor or accomplishment.

Without experimental science man would be to-day in his primitive state, or more likely he would have become exterminated long since in his unequal contest with the elements and the brute creation. Even in his most perfect physical development he is inferior to many of the lower animals in muscular strength, fleetness and range of sense recognition; but he is unique among animals in the development of the instinct of inquisitiveness. He wants to know, therefore, he experiments. He observes the effect of altered environment, and his interest in experimentation grows in scope and purpose. He ascertains that when certain definite relations are established, the results are constant. He slowly develops an appreciation of causal relationship. After countless generations of crude experimentation, careless observation and faulty generalization, he sees the necessity of greater exactitude in his experimentation. In this way, slowly and laboriously, the sciences have been evolved. With periods of barrenness of variable length, some of which have extended through many consecutive centuries, man has slowly progressed from his primitive state to his present condition. Scientists, the greatest benefactors of the race, have always been few in number, but their work has benefited many. In some ages the masses have been too ignorant to utilize the scientific knowledge possessed and enjoyed by their ancestors and have shown marked retrogression. The most potent causes of these lapses have been disease, war and famine. In no age, not even the present, has scientific training touched more than a small part of the generation.

Some primitive man learned that fire could be kindled by friction between pieces of wood or that a spark could be struck with flint. What benefit came from this simple discovery? It gave protection from the cold of winter and greatly extended the range of man's activities. The camp fire, now started when and where he willed, frightened away beasts of prey, served to cook his food and formed the nucleus of a primitive home. One day, ore being used as stones for the crude hearth, metal is found in the ashes and the flint age is passed and that of metal has come. Century after century passes; accidental discovery is replaced by systematic investigation, and the science of metallurgy with its multiple benefits is developed.

Primitive man crouched in terror when darkness enveloped the earth at noon day. He could see in this only the angry disapproval of an all-powerful God. The stars were supposed to control the destinies of individuals, communities and nations. The motions of the celestial bodies were observed, the heavens were charted and astrology became astronomy.

Primitive man fed upon such fruits, vegetables, nuts and berries as the soil gratuitously offered him, eked out with the uncertain product of the chase. Experience showed that the productivity of the soil would be greatly increased by tillage, and that certain animals could be domesticated easily and made to serve man in life and after death. Having the breeding and feeding of these animals under his direct control, he has learned to modify them to suit his purpose. From a common stock he has evolved the draft, race and trotting horse, each with many variations. From the wild grains he has produced many varieties of each cereal, while at the same time he has increased the yield more than a hundredfold. By irrigation and cultivation he has converted thousands of acres of barren

desert into fields of golden grain, dotted with orchards bearing luscious fruits. When the territory now within our national continental boundaries was occupied by savage man, it supported only a few thousands, now under the stimulus of scientific agriculture it feeds, shelters, clothes, supplies the necessities of life to all and untold luxuries to many of its ninety millions of inhabitants and sends abroad enough to feed other millions.

In the long ago, some man observed the magnifying effect of a natural lens. The lapidary labored through centuries in the perfection and proper adjustment of lenses. The result was the evolution of the compound microscope. In 1849 a village doctor on the Rhine studied the blood of animals sick with anthrax under his crude microscope and compared it with the blood of healthy animals. He discovered the bacillus of this disease. This work under the genius and diligence of Davaine, Pasteur, Koch and others demonstrated the causal relationship between microorganisms and disease. The science of preventive medicine has been developed, the average of human life has been lengthened by fifteen years within one century and the way has been made clear for a like prolongation within a like period, provided the masses of the people acquire sufficient intelligence to properly utilize the facts already known. The capacity of the individual for work, rational pleasure and intellectual growth has been multiplied. Pestilential regions have been converted into fit dwelling places for man and his dominion over antagonistic conditions and forces of nature has been extended. Disease, which hitherto has excluded man from the fairest portions of the earth, has exacted heavy toll in all climes, has wrecked the greatest civilizations of ancient times and has more than once threatened the race with extinction, is now largely under man's control.

The foregoing are only illustrations of what science has done in the improvement of our race. I know of no scientific discovery which has not aided in the betterment of mankind and still science is in its infancy. Its ultimate goal is the domination of the forces of nature and their utilization in the betterment of mankind.

The fundamental principles and facts of the physical, chemical and biological sciences must be included in the courses taken by every student who wishes a broad, symmetrical education, whatever his business or professional calling is to be. Moreover, training in these sciences should not be of the amateur kind, but should be sound and thorough and accompanied by laboratory observation and demonstration. It should supply a sound basis which will enable the student in after life to reach correct conclusions, when scientific judgments must influence his behavior. The failure of those in high places to appreciate the value of scientific equipment and procedure has proved to be a serious matter many times. The importance of this subject justifies the mention of specific instances. When the Spanish-American War began in 1898, Congress refused to make appropriation for scientific medical equipment. The graduates of West Point up to that time had no instruction in army sanitation. Not a regiment, either regular or volunteer, went into the field with the medical equipment necessary to recognize either malaria or typhoid fever. Regimental commanders paid no heed at first to the protests of medical officers as to the location and sanitation of camps. The result was nearly twenty thousand cases of typhoid with more deaths from disease than from the shots of the enemy. Still, the only golden chapter in the history of that war is that which records the discovery of the manner of transmission of yellow fever, the lifting of the curse of this disease from the "Pearl of the Antilles" and the subsequent construction of the Panama Canal, made possible by this discovery.

The officials of the state of California denied the existence of the plague in San Francisco in face of the fact that its presence had been demonstrated scientifically. The result was the infection of certain rodents throughout a large territory and the expenditure of lives, money and energy in its eradication.

Duluth placed the outlet of its sewers and the intake of its water supply in close prox-

imity and paid for its ignorance in an epidemic of typhoid. A list of cities which have made similar mistakes is too long to give; a list of those which have followed scientific teaching would be shorter.

As I have indicated, our inability to utilize the known facts of preventive medicine means that the aggregate of human life in our population of one hundred million will measure one billion five hundred million less in years than it would were we, in the mass, more intelligent. This is a trustworthy and conservative statement of the stupendous price that this generation is paying for the ignorance of the many and for the special activities of Christian Science, the league for medical freedom and other impedimenta to the progress of scientific sanitation, which so far have been potent enough to block much needed legislation. There are many men directing our local, state and national affairs, among them graduates of our greatest universities and best colleges, who are as ignorant of, consequently as indifferent to, these matters which so seriously affect our national life—present and future—as are the untaught hordes that crowd into our country like so many cattle, through the gates of Ellis Island.

The fatalities due to ignorance of science make big figures in the mortality tables. Whether the infant lives or not depends most largely upon the scientific knowledge of the one who feeds it, and many a mother, who would give her life to save her child, murders it through ignorance. Surely, ignorance of such scientific knowledge as is necessary to protect health and life is a crime, a moral, if not a statutory one.

Descartes said that the purpose of all education is to enable one to reach sound judgment. Daily most of us are compelled to reach some judgment founded on scientific knowledge and training, and yet many college graduates are lacking not only in the knowledge but in the capability of comprehending it when presented.

I have indicated the subjects which in my opinion are essential to a liberal education, and I wish to add something about methods of study. It is a fallacy to suppose that every man who takes a college course gets an education and that all who do not have this privilege fail to be educated. The best university with the most complete equipment and the most learned faculty can do no more than supply opportunities. An education is not secured without effort on the part of the student. Too many college students follow lines of least resistance, dissipating instead of concentrating their energies, fall into bad habits, and instead of being improved are harmed by college residence. This is shown by their subsequent behavior. Forty years have I been in this university as student and teacher, long enough to see many uncouth, unpromising lads develop into eminent jurists, skilful engineers, able physicians and surgeons and, in short, honoring alike themselves and their alma mater in widely diversified spheres of activity by their deeds, but to-day I recall many who have been cast as useless driftwood upon the shores of life's sea. Were I asked to name the rocks which have caused the greater part of this wreckage I would mention—first of all, those that lie about the alluring islands of idleness. Inherited defects are not common among university students. The fact that they have been directed wisely at the start is proof of this, but it requires personal strength of character and fixedness of purpose to hold to the course. Next, but far less in number, are the high reefs of active dissipation. Lighthouses show their location and warn the sailor of danger, but he thinks he can pass through the narrows, where so many, less skilful than he, have been wrecked; he takes the risk and goes on to the rocks.

I drop the simile of the sailor and the rocks and continue my illustrations. One finds that he needs a knowledge of French or German in order to secure the fullest information. He elects the subject for one semester, works indifferently and fails. He concludes that he has no aptitude for language and tries something in another line in like spirit and with like result. Some men spend their lives in trying to find out what they are good for and die good for nothing. In my basic statements

I have emphasized the fact that effort is necessary in order to open pathways to the cerebral cortex and that *educatio strenua* is the only genuine article.

While I have made an earnest plea for a broad, liberal, fundamental education in order that we may be in intelligent touch with the basic conditions that control and modify human behavior, there is like physiological reason for advising every student to build on this broad foundation his specialty. When you have reared your house with heavy rocks for the foundation, massive walls, bound together with steel beams, on this you can carry up as high as you please the tower which will afford you an outlook. Take one subject and know everything that is known about it and if possible know more than any one else. In other words, in addition to your general knowledge be a specialist. To your general knowledge add the skill of the expert. The physiological reasons for this advice must be evident to all who have followed my line of argument. Neural pathways become smoother the more frequent the travel over them. I recommend expert development for the following reasons: (1) Extension of the domain of knowledge is secured. (2) The pleasure known only to the discoverer comes to him who does work of this kind. (3) It is a rest and recreation to turn into the well-worn paths along which thought moves automatically.

It is not essential that the special study, which I recommend, should be in the line of one's vocation. It may lie quite apart from business or professional duties.

The history of intellectual progress is quite in accord with the teaching that a broad educational foundation with the addition of expert learning gives the best results. I will mention a few illustrations of the educational training of men who have advanced human knowledge. William Herschell was a music teacher and never saw a telescope until he was thirty-five. His hobby was to grind lenses and make perfect mirrors. With these he discovered worlds, systems and universes. His great reflectors caught up light which left its source two million years ago. Our solar system became a mere speck in the range of his vision. Burnham became an enthusiast in the study of double stars, of which he discovered a thousand while he was still a stenographer in a Chicago court. Hutton, physician, chemist and farmer, showed that the earth's crust is a stone book, made up of pages, chapters and volumes. William Smith, the English surveyor, without college training, demonstrated that the characters used in this great stone book are the fossils. Cuvier, an anatomist, was the first to read some of the chapters in the history of the building of the earth. Buckland, doctor of divinity, extended the reading. Perraudin, the chamois hunter, suggested glacial action in shaping the earth's crust. The fox-hunter, Murchison, with Sedgwick, named the volumes of the stone book in order of their issue. Priestley, the dissenting clergyman, discovered oxygen. The Quaker physician, Thomas Young, the real discoverer of the undulatory theory of light, published many of his papers anonymously for fear that the rumor that he was a scientific investigator would injure his practise. Furthermore, he devoted some of his spare time to deciphering Egyptian hieroglyphics. Lavoiser, the father of chemistry, went to the guillotine. The official while signing his death warrant said: "The Republic has no need of savants." The honor of discovering the mechanical equivalent of heat and laying the foundation of the law of the conservation of energy is divided between the Manchester manufacturer, Joule, and the German village doctor, Mayer. The self-trained Quaker boy, John Dalton, became the founder of the atomic theory. Jefferson was the framer of the Declaration of Independence, president of the United States, founder of the University of Virginia and student of natural history. Franklin was printer, author, envoy from the young republic to France, postmaster general and scientist. The autocrat of the breakfast table was professor of anatomy in Harvard Medical School and his greatest contribution will not be found in his novels or poems, but in his article on the

"Etiology of Puerperal Fever," in which he divides honors with the great Hungarian obstetrician, Semelweiss. It is said of Goethe that he might have been the greatest scientist of his age had he not chosen to be the greatest poet. The man who made the greatest contribution to medicine in the nineteenth century, Pasteur, was not a physician, but a chemist. Elihu Burritt with his knowledge of many languages was a blacksmith. Virchow, the father of cellular pathology, was a socialistic-democrat, a member of the Reichstag and a vigorous opponent of Bismarck.

Permit me to briefly summarize my chief themes: Education is the modification of behavior through experience. The mechanism of learning consists of the nervous system with its sense receptors, conductors, centers and effectors. Education is secured by opening up neural pathways to the brain; this requires effort, but a frequently traveled path becomes smooth and easy. The course of learning does not show a constant ascent, but has occasional plateaus. Special pathways are needed for the acquisition of special knowledge. A fundamental education should include language, mathematics, history and science. No education can be symmetrical without training in all these. Upon these as foundation stones, the tower of special knowledge may be carried as high as the builder can.

Accuracy and promptness in formulating judgment are the ends sought in education; correctness first, and readiness next. When these qualifications are accompanied by the ability to be both prompt and effective in action the individual becomes of highest service to himself and his fellows.

I am aware of the fact that the advice of age does not meet a ready reception in the mind of youth. The old frequently envy youth its opportunities and wish that they were again young. This is idle and besides is not desirable. My generation has enjoyed great privileges. It has been my personal good fortune to know in the prime of life that great Englishman, the founder of antiseptic surgery, Joseph Lister, to sit at the feet of that great German, the discoverer of the tubercle bacillus, Robert Koch, and to look into the face of that greatest of Frenchmen, the man who laid the foundations of preventive medicine, Louis Pasteur. Were the price offered eternal youth, I would not tear from memory's book one page of its golden lessons, and I ask no higher immortality than that there should be found among my students those who have been inspired by my words and works, to carry forward the torch of science to light their fellow-men on their way to wider knowledge and its beneficent rewards.

Man has already accomplished much, but the greater tasks lie ahead. The productivity of the soil must be increased a hundredfold. Grains and fruits, yet unknown, must be grown. The heavy burdens that still oppress the shoulders of labor must be transferred to the tireless muscles of machinery. The literature of the higher civilization is, as yet, unwritten. Laws for which no precedents can be found must be framed and administered. The giant strength of intra-molecular energy must be harnessed into the service of man. A broader morality must govern our behavior, one to another, and a loftier religion must enthuse the common aspirations of the race. All this and much more must be achieved before man fully develops his highest potential greatness.

The world of effort is before you, young men and women. The road ad astra lies per aspera, but bruised heels and aching limbs count for naught when the way leads upward toward the mountain tops of human growth and perfection. Keep to this road, doing what you can to lift yourself and your fellows to a more rational life, and Michigan will have done well in bestowing upon you her richest gift, an education.

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THE USES FOR MATHEMATICS

MATHEMATICS has been termed the handmaiden of the sciences. Whether or not the mathematician himself accepts this as a truthful representation of his beloved science de-